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Report No. 65-35
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ANNUAL PROGRESS REPORT, MAY 31, 1965
OPTIMUM STRUCTURAL DESIGN PROJECT

Department of Engineering
University of California
Los Angeles, California

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1. Introduction

One of the primary goals of aerospace structural research during the last twenty years has been the development of efficient, low-weight structures. During recent years similar research has been conducted in the area of civil structures in search of economy in the use of structural materials. Optimum structural design is basically concerned with the selection of a structural configuration and material that will allow the structure to transmit forces with the minimum possible weight. There are, of course, other criteria, such as minimum cost, serviceability, and stiffness that must be considered in any structural design. The methods of optimum design provide the designer with the ability to show the weight penalties involved in the consideration of these other criteria. One of the advantages of these design techniques is that any method of stress analysis that accurately predicts behavior is usable and, in the absence of acceptable analytical methods, the results of tests may be utilized. The purpose of the current research project is to put optimum design on a sound engineering basis and to substantiate the extension of optimum design methods to more complex structures by test programs.

Several investigations have been conducted during the second year of the project, primarily by graduate students. This progress report takes the form of a series of abstracts covering the various investigations.

2. Bending of Wide Beams

Theoretical optimum relationships were derived for trapezoidal corrugations in bending[1]. The cross section of the beams was optimized by arranging the width of the panel elements such that two modes of failure occurred simultaneously. The two modes of failure considered were local buckling of

the compression panel and local buckling of the web panel in bending. The corrugation that resulted from this optimization has an angle from the horizontal of 52.2° and the web panel is 2.44 times larger than the compression and tension panels.

Fourteen tests were run on 60° flat corrugated beams with equal panel widths. These beams were tested to check the theoretical prediction because of the ease of fabrication. The beams were loaded at the third points so that the center of the beam was subjected to a constant bending moment with no shear. A picture of the test set-up is shown in Figure 1.

The test data is shown compared to the theory in Figure 2. The initial buckling points correspond very well in the elastic range but there is some error in the inelastic or high structural index range. This discrepancy between test and theory in the inelastic range is due to the fact that the bending modulus of rupture is used as the theoretical buckling stress. All of the test specimens were slightly stronger than predicted. If the initial buckling of the beams is not considered as failure, efficiency can be gained by allowing the beams to reach their maximum stress. The circled test points corresponding to the maximum load illustrate this added efficiency. The data seem to follow the von Kármán postbuckling theory shown as a dashed line in Figure 2.

This theoretical development was an extension of the work done by Shanley in Reference 2.

3. Torsion of Pentagonal Tubes

A theoretical study of optimum tubes in torsion has indicated that pentagonal tubes are more efficient than square or round tubing.* A test program is underway to check this theoretical development. A torsion testing machine has been built that will test tubes up to approximately eighteen inches in diameter. The machine is capable of applying a torque of 300,000 inch-pounds.

*R. Taylor is conducting an M.S. thesis study on this subject.

4. Torsion of Corrugated Cylinders

A theoretical and experimental study of the behavior of corrugated cylinders in torsion is underway.* Tests have been conducted to check the buckling strength of these cylinders in both the local and general instability modes.

5. Shear of Corrugated Plates

The behavior of corrugated shear plates is currently being studied. An experimental program has been designed to investigate the local and general instability modes of failure of corrugated shear plates. A fixture for testing these plates has been designed and built. The fixture is a "picture-frame" type of apparatus incorporating crossed flexure pivots at the corners.

6. Other Work Planned or Beginning

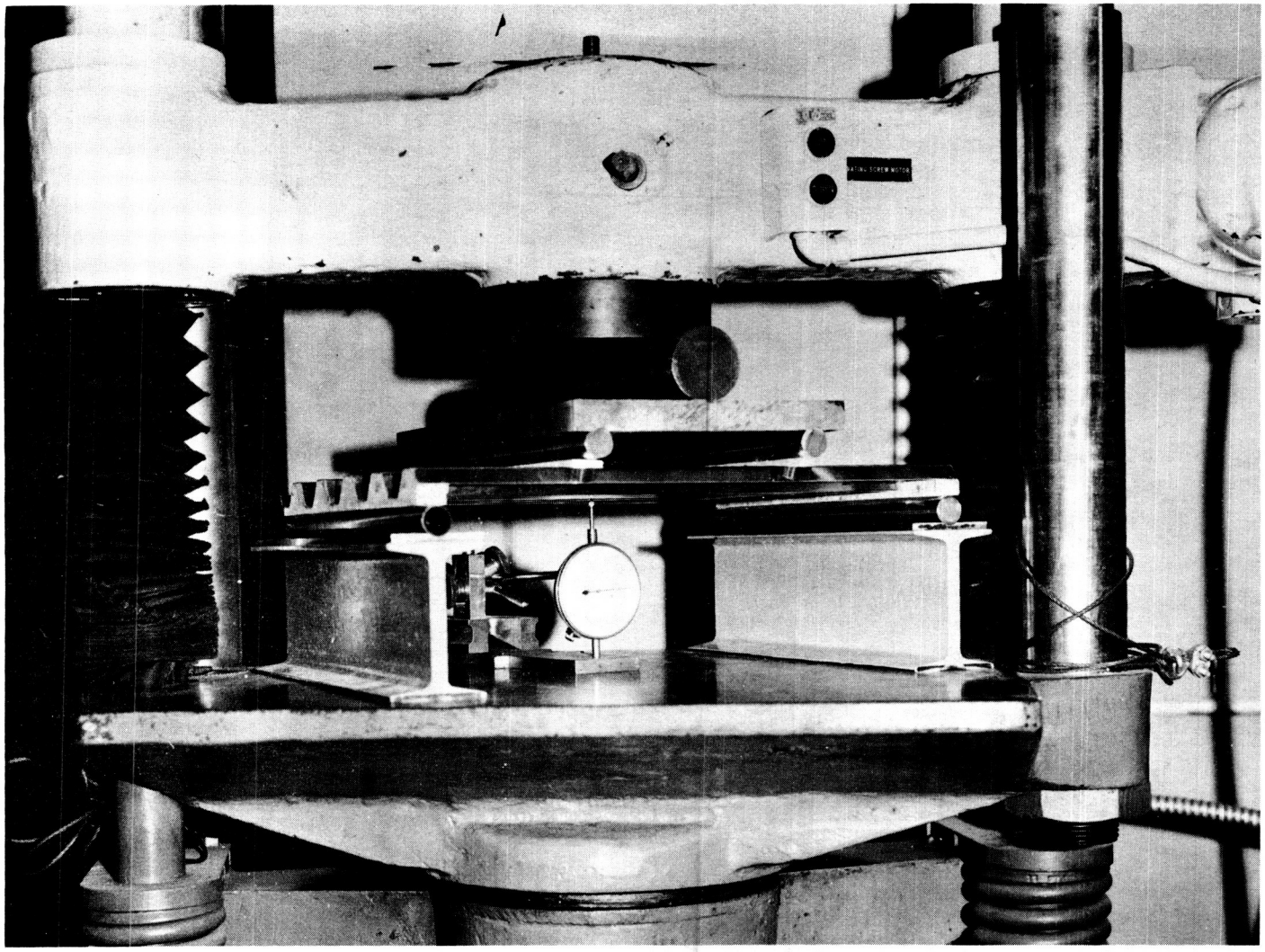
Other studies are being undertaken during the summer. These are:

a. An experimental study of the bending modulus of rupture of round tubes.

b. A theoretical and experimental study of the optimum design of square tubes in bending. This will include postbuckling behavior.

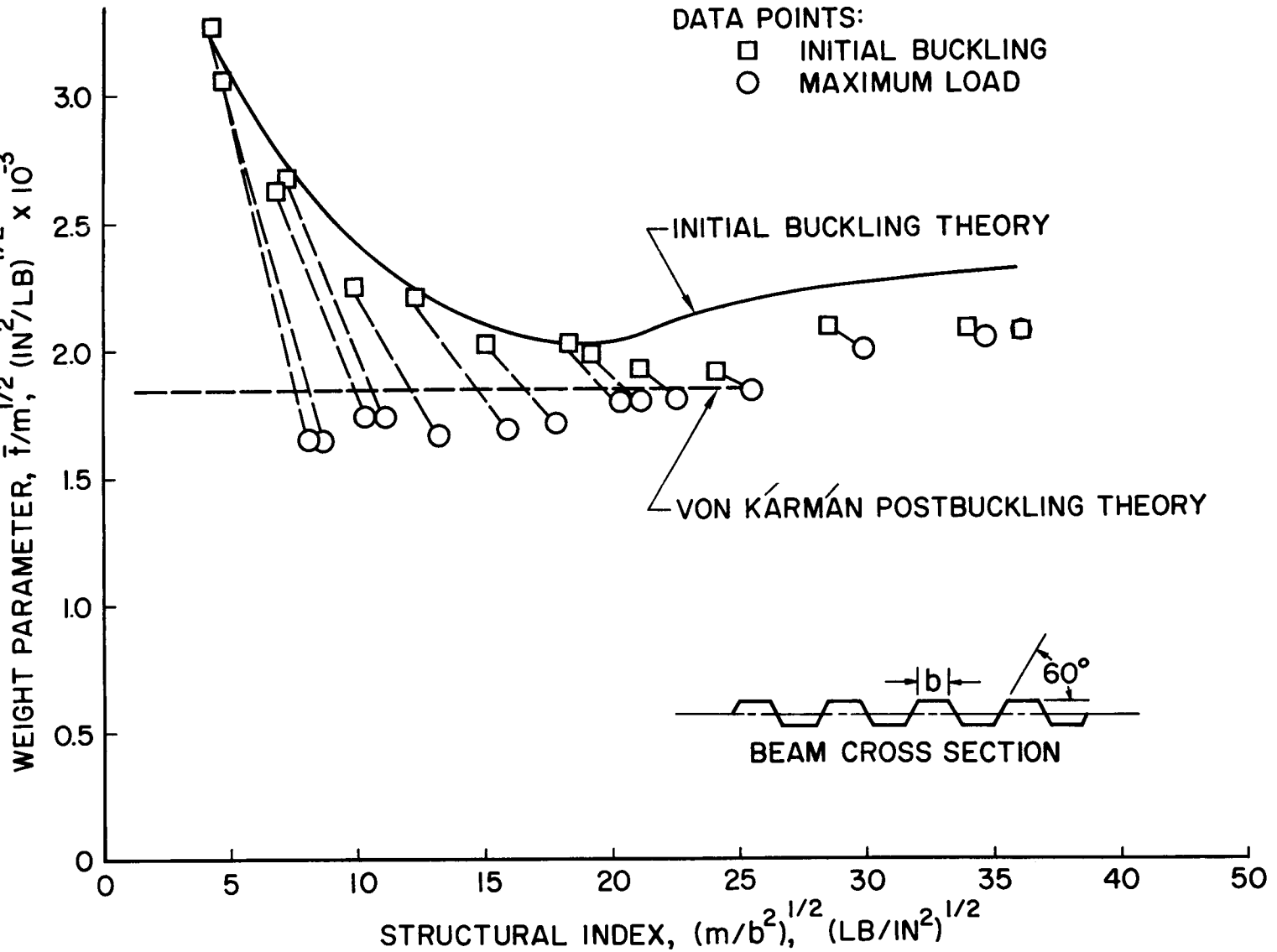
c. A theoretical study of the optimum design of columns supported by tension ties.

d. A study of the optimum design of structural systems including probabilistic considerations.



WIDE BEAM TEST APPARATUS

FIGURE 1



WIDE BEAM TEST DATA
2024 - T3 ALUMINUM

FIGURE 2

REFERENCES

1. Magie, M. H., "Optimum Design of Wide Beams," UCLA M.S. thesis, June 1965.

2. Shanley, F. R., "Relative Advantages of Buckling-Resistant and Post-Buckling Structures," presented at the International Colloquium on Comportement Postcritique, The University of Liège, November 12-13, 1962, Liège, Belgium.